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The effect of wastewater from paper mills on the operation of primary stages in the municipal wastewater treatment plant

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ABSTRACT
Annually, paper and paperboard manufacture generates significant volumes of wastewater with varied composition. The issue of solid substances constitutes a problem for the protection of the quality of water resources as they may cause a series of undesirable effects on aquatic ecosystems due to deposition and anaerobic fermentation processes. The reference document on best available techniques (BAT) of the European Union recommends the treatment of industrial wastewater together with sewage wastewater and this paper studies the effect of the effluent from a paper mill on the functioning of the primary treatment (mechanical and chemical) from a municipal wastewater treatment plant. The results show higher efficiencies for the removal of pollutants in the case of coagulation-flocculation treatment compared to the efficiencies attained in the case of gravitational sedimentation of suspended solids. The effluent may be discharged in the sewer as it does not affect the flow of sewage wastewater and may be subjected to conventional wastewater treatment processes which, in optimal operating conditions, may lead to quality parameters according to the normative regarding the discharge of wastewater in the environment.
Keywords: *chemical treatment, mechanical treatment, recovered paper, wastewater.*

1. INTRODUCTION

Paper is an inexpensive and easy to obtain product and a waste frequently met in all the activities. In the context of sustainable development, the benefits of paper recycling are very important and refer to the saving of the natural resources and the reduction of harmful emissions in the environment. The European Recovered Paper Council (ERPC) announced an impressive 71.5% paper recycling rate for Europe in their monitoring report for 2015 [1].

This paper comprises mainly the research regarding the wastewater resulting from paper and paperboard manufacture in case that paper waste without de-inking are used as raw material.

The raw and auxiliary materials used in the technological process are [2,3]:

- paper and paperboard, pasteboard, unbleached sulphate cellulose;
- mineral filling (kaolin, calcium carbonate, talcum, titanium dioxide), organic filling (starch, latex), dyes, retention agents, aluminium sulphate.

The technological operations employed in the manufacturing process are [2,3]:

- processing of raw materials through disintegration, sorting, filling, pasting and dyeing;
- dehydration of the obtained pasta;
- formation of a continuous sheet of paper or paperboard;
- drying, cutting and packing of the final products.

Wastewater resulting from paper industry are characterised by high flow rates and varied loads of suspended matter, organic substances, nitrogen compounds and other contaminants (heavy metals, salts etc.) [4]. Modern paper mills use internal recycling systems in order to maximize the use of cellulose fibres and for the rational use of water [5]. Wastewater are subjected to a local separation in order to reuse the suspended particles in the technological process, and the clarified water is discharged in the municipal sewer and sent to the municipal wastewater treatment plant prior to its discharge in the natural receptors.

Generally, the treatment of municipal wastewater (sewage and industrial) is achieved through mechanical, chemical and biological methods.

The mechanical methods ensure the removal of coarse components, of sedimentary contaminants and of floating or floatable components. This methods rely on physical separation processes and are largely used as primary treatment processes, providing the removal of 50-70% of the suspended solids and 30-40% of the organic substances [6].

Chemical treatment is used for the processing of dissolved or colloidal substances from wastewater. Physicochemical processes take place and the pollutants are transformed in substances that separate more easily or in substances with less harmful activity or in substances more susceptible to removal. An optimum controlled wastewater treatment process highlights removal efficiencies of 80-90% for suspended matter, 40-70% for organic substances and 80-90% for bacteria [7,8]. Usually, iron and aluminium salts are used as chemical reagents: $FeSO_4$, $Al_2(SO_4)_3$, $AlCl_3$ etc. [9]. Specialised literature shows that aluminium sulphate recovered from metallurgical slags using a Romanian patented method may be a viable alternative as this product shows good coagulation properties, comparable to aluminium sulphate obtained from natural raw material (bauxite) [10-12].

The biological treatment consists in the degradation of organic pollutants under the action of microorganisms and the transformation of these pollutants in harmless substances. Physical and biochemical processes take place [13].

In the following, a case study regarding the adequate treatment of wastewater from a paper mill is presented and the influence of pollutant load on the operation of primary treatment (mechanical and chemical) from municipal wastewater treatment plant is depicted.

2. EXPERIMENTAL SECTION

In order to evaluate the quality of wastewater, 5 sampling campaigns were conducted. The main water quality indicators were analysed (organic substances expressed as COD and BOD_5, suspended solids, nitrogen, phosphorus) based on standardised methods and using conventional and instrumental analysis methods [14-19].

Experiments simulating mechanical and chemical treatment using aluminium sulphate were conducted in laboratory set-ups and several types of wastewaters were employed:

- the influent of the wastewater that does not contain the effluent from the paper mill (IWTP);

- a mixture (A) consisting of paper mill effluent (EPM) and sewage wastewater (IWTP) 1:30 (v:v) (according to the ratio between the water flows of each category of wastewater).

The results were evaluated by determining the treatment efficiencies and by conducting a comparative analysis of the studies processes (mechanical and chemical).

Mechanical treatment. The simulation at laboratory scale of the mechanical treatment process, namely the gravitational sedimentation of suspended matter, was achieved in Imhoff cones. Within the experiments, one has assessed:

- the dynamics of sedimentation for a time period of two hours;

- the volumes and the basic characteristics of the sludge generated after two hours of sedimentation (dry substance and volatile substances);

- the removal efficiency of pollutants by sedimentation.

Chemical treatment. The simulation at laboratory scale of the functioning of the chemical treatment consisted in the coagulation-flocculation of the wastewaters using the Jar test and the gravitational sedimentation of the chemical sludge resulting in the Imhoff cones [20].

The substances used for wastewater treatment were: aluminium sulphate commercially available Kemira ALG (EN 878:2004, Kemwater Cristal Comp.) and a flocculation agent Floerger FR 1023 (anionic polyelectrolyte).

At the end of the experimental procedure, the degree of pollutant removal was evaluated together with the main characteristics of the chemical sludge.

3. RESULTS SECTION

The wastewaters used in experiments were analyzed and the results are presented graphically in Figures 1-3.

Mixture A consisting of EPM and IWTP 1:30 (v:v) has the quality characteristics of IWTP and the indicators where EPM had high values were significantly changed. On average, mixture A was characterised by higher values compared to EPM, with approx. 16% for COD, 22% for BOD_5 and 11% for suspended solids. As regards the ratio between the biodegradable substances and the biogenic substances (nitrogen and phosphorus) BOD_5:N:P, values specific to municipal wastewater were recorded, similar to IWTP.

The mechanical treatment was conducted at laboratory scale and it was observed that both wastewater types (IWTP and A) have an ascending and similar dynamics for the sedimentation of suspended solids, the sedimentation curves shown in Figure 4 being very close. The volume of the chemical sludge varied between 3.3-6.8 mL/L of wastewater for IWTP and between 3.5-6.2 mL/L wastewater for mixture A. The humidity of the sludge after two hours of sedimentation was approx. 95.7% for IWTP and approx. 96% for mixture A.

The available experimental results were processed using a statistical correlation technique in order to establish a mathematical expression between the initial concentration of suspended matter and the volume of the sludge after two hours of gravitational sedimentation. The relationship between the variables is linear (Figure 5) and it allows the estimation of the volume of sludge for the industrial exploitation of the decanter.

The content of suspended solids in the water subjected to sedimentation for 2 hours is, on average, 11% higher in the case of mixture A compared to IWTP; this may be explained by the additional load of raw wastewater subjected to the separation of suspended solids. The efficiency of the sedimentation was practically similar for both categories of wastewater, namely 39-70% for the removal of suspended matter from IWTP and 39-67% for the removal of suspended matter from mixture A.

The simulation of the chemical treatment process at laboratory scale was conducted on a well-established experimental design. The wastewater was introduced in reaction vessels and put in contact with the (predetermined) optimum dose of coagulation agent for a rapid dispersion of the reagent in the water volume. In the second phase, the agglomeration of the microfloccs was achieved by means of specific flocculation agent and slow mixing. In the last phase, the gravitational sedimentation of the larger floccs took place for 2 hours.

For both types of wastewaters (IWTP and mixture A), a significant reduction of their turbidity and colour was observed. The sedimentation curves for the resulting chemical sludge are compared in Figure 5. The volume of sediment deposited after 2 hours varied between 1.7-12 mL/L of wastewater for IWTP and between 2.5-17 mL/L of wastewater for mixture A. The decanted sludge had different contents of mineral and volatile substances, namely 3.1-6.7% mineral substances and 64-80% volatile substances for IWTP and 2.6-8.1% mineral substances and 64-80% volatile substances for mixture A. These data highlight the fact that the volumes and the characteristics of the chemical sludge vary within a wide domain regardless of the type of the effluent.

The experimental results on the chemical treatment of wastewaters showed that a partial entrainment of the contaminants takes place; the removal efficiencies obtained for municipal wastewaters (IWTP) and for the mixture of wastewater (A) are listed in Table 1.

Starting from a multitude of data and observations regarding the two treatment processes mainly employed in wastewater treatment, a comparative analysis was conducted and it highlighted the significant percentage reduction of contaminants in the case of chemical treatment of wastewaters. Generally, the differences between the efficiencies of pollutants removal from mixture A compared to IWTP are slightly higher (over 20%) for phosphorus and slightly lower (under 20%) for the rest of the indicators (suspended matter, COD, BOD_5, nitrogen). Another important observation is related to the increase of the quantity of primary sludge resulting in case that municipal wastewater and the effluent of the paper mill are mixed.

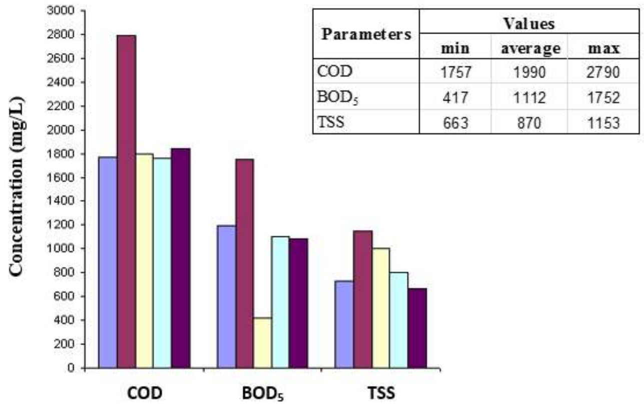

Figure 1. The variation of the quality of wastewater discharged by the paper mill (EPM).

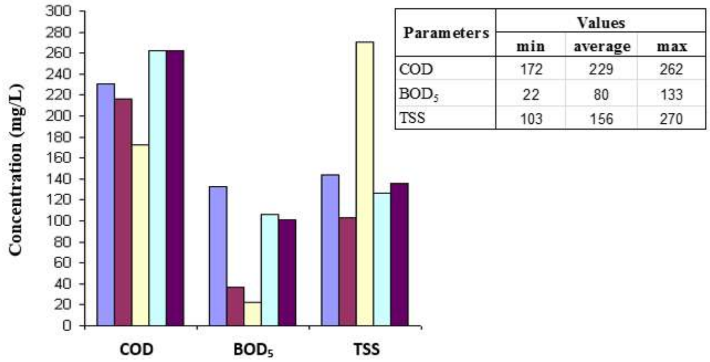

Figure 2. The variation of the quality of the influent from the municipal wastewater treatment plant that does not contain the effluent from the paper mill (IWTP).

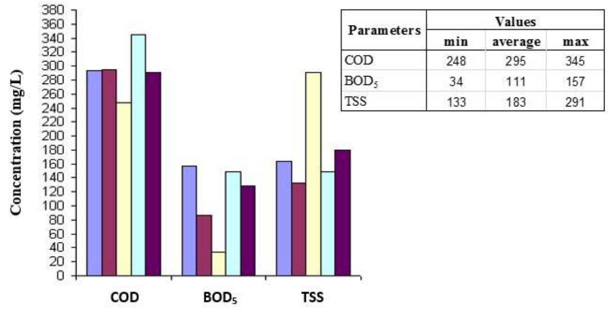

Figure 3. The variation of the quality of wastewaters for mixture (A) between EPM and IWETP 1:30 (v:v).

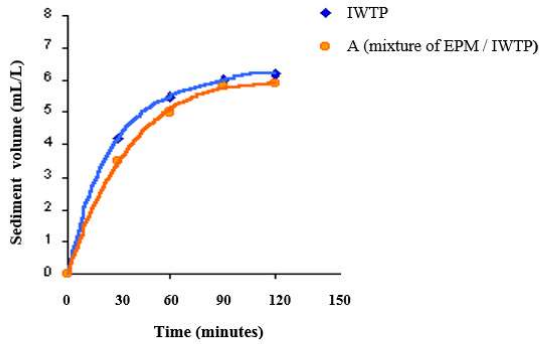

Figure 4. The dynamics of the gravitational sedimentation of suspended matter.

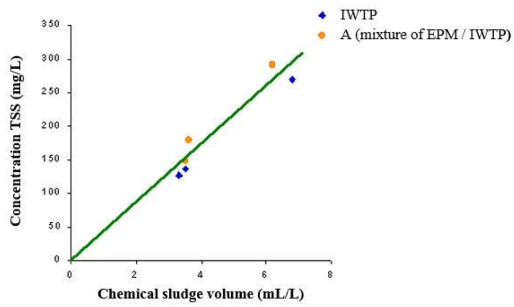

Figure 5. The correlation between the initial concentration of suspended solids from wastewater and the volume of chemical sludge after 2 hours of gravitational sedimentation

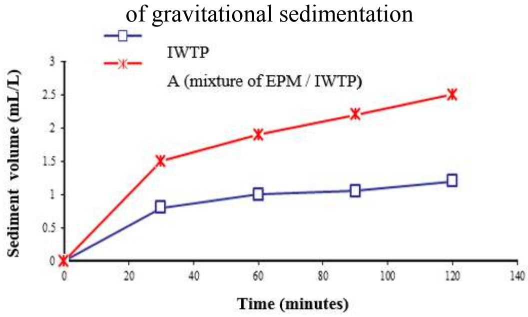

Figure 6. The sedimentation curves for the chemical sludge resulting from the coagulation-flocculation of the wastewaters.

Table 1. The efficiencies of pollutants removal from the chemically treated wastewaters.

Quality parameters	Efficiencies (%)	
	Municipal wastewater, (IWTP)	Mixture of wastewaters, (A)
COD (chemical oxygen demand)	5 - 51 29	3 - 54 26
BOD_5 (biochemical oxygen demand)	6 - 52 29	11 - 42 29
Total suspended solids (TSS)	40 - 85 60	16 - 67 52
Nitrogen (N)	6 - 29 15	10 - 28 16
Phosphorus (P)	6 - 52 29	24 - 40 32

4. CONCLUSIONS

Wastewater from paper mills are contaminated with cellulosic fibres and colloids resulting from the filling and pasting operations and with dissolved substances resulting from bleaching (if needed) and dyeing operations. The suspended matter and dye wastes may have a harmful effect on the quality of the emissary and on the facilities located downstream, so the treatment of the effluent is necessary and in most of the times is achieved together with the municipal wastewaters.

This paper establishes the effect of the effluent resulting from a paper mill that uses as raw materials mainly paper waste without de-inking on the primary treatment steps from a municipal wastewater treatment plant. Although the mixture of wastewaters has a composition specific to municipal wastewaters, the designing of an industrial installation must take into consideration the volume contribution of the paper mill effluent that leads to an increase of the water quality due to the significant loading with contaminants (suspended matter and organic substances in the range of hundreds and even thousands of mg/L).

The suspended matter from the paper mill effluent results from the recovery of the cellulosic fibres and has a slow sedimentation rate. Thus, one may conclude that there are no problems related to its deposition and the reduction of the flow section of the sewer when these wastewaters are discharged in the municipal sewer. On the other hand, the experiments showed that this type of suspended solids may be removed in the primary treatment step in the municipal wastewater treatment plant by means of co-sedimentation (absorption and/or coagulation-flocculation) together with the suspended matter from the sewage.

The removal efficiencies for chemical treatment using aluminium sulphate were higher compared to the efficiencies of gravitational sedimentation; the differences were up to 22% for suspended matter, 29% for COD, 26% for BOD_5 and 32% for phosphorus. As expected, the volume of the sludge and its characteristics varied according to the treatment process; as such, the adjustment of sludge processing installation is required.

In the last decades, ensuring the life standards and the economic growth demand an excessive use of water resources and, in this context, the adequate wastewater treatment is the main means of water quality protection. The research depicted in this paper enlists in the domain of interest for the specialists that design and operate the municipal wastewater treatment plants as the contribution of industrial wastewaters is decisive for the evolution of the wastewater treatment and for the expected results.

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